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(54) TRANSFORMER COOLING

(71) We, G.E.C. SOUTH AFRICA (PROPRIETARY) LIMITED, a South African Company of 11th Road, Kew, Johannesburg, Transvaal Province, Republic of South Africa, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to the cooling of electrical transformers.

According to one aspect of the present invention there is provided an electrical transformer comprising a transformer tank which houses the transformer core and winding structure, and an oil cooling system the flow of oil through which results entirely from thermo-syphonic action, said cooling system being connected to an upper portion of said tank so that heated oil can flow from the tank to the cooling system and being further connected to a lower portion of said tank so that cooled oil can flow from the cooling system back to the tank, and said cooling system comprising a first header, a second header spaced from the first header, and a bank of side-by-side radiator tubes connecting said first and second headers, the longitudinal axes of the tubes being arranged at an angle not exceeding 40° with respect to the horizontal, and a plane containing the longitudinal axes of the tubes having a longitudinal axis which is parallel to the axes of the tubes and a transverse axis which is substantially horizontal.

The preferred disposition of the tubes is horizontal although they can be inclined within the limit defined above. If the tubes are inclined then an angle of inclination not exceeding 10 degrees is preferred to an angle of inclination greater than 10 degrees but not exceeding 15 degrees, this latter range is preferred to the range of more than 15 degrees but not exceeding 20 degrees which is in turn preferred to the range of more than 20 degrees but not exceeding 30 degrees. Relatively steep inclinations of more than 30 degrees are believed by applicants to be least desirable.

Said tubes can be elliptical in cross-section with their maximum dimension vertical and can, in addition, be finned.

In one constructional form the transformer comprises more than one bank of tubes, the tubes in each bank being side-by-side, and the banks being connected in series with one another and arranged one above the other.

In another constructional form, said bank of tubes lies alongside wall of the tank and extends parallel thereto. Where, in this constructional form, there is more than one bank of tubes, said banks of tubes can lie alongside the side wall of the tank, extend parallel thereto, be one above the other and be connected in series.

In a further constructional form, said bank of tubes and said headers can be above the level of the top of the tank.

In yet another constructional form, the first header can be connected by a tank outlet pipe to the upper portion of the tank, and the second header can be connected by a tank inlet pipe to the lower portion of the tank. In this form, one of the headers can lie alongside a side wall of the tank and said radiator tubes can extend from said one header in the direction away from said side wall. The header which lies alongside said side wall can be the first header, and in this form the tank inlet pipe can extend downwardly from the second header to the lower portion of the tank and serve as a support for the second header.

For a better understanding of the present invention and to show how the same may be carried into effect, reference will now be made, by way of example, to the accompanying drawings in which:—

Figures 1, 2 and 3 are respectively a side elevation, a rear elevation and a plan view of a first form of transformer according to the present invention;

Figures 4, 5 and 6 are respectively a side elevation, a rear elevation and a top view of a further form of transformer;

Figures 7, 8 and 9 are respectively a side elevation, a front elevation and a top plan view of a third form of transformer; and

Figures 10 and 11 are respectively a side

elevation and an end elevation of a fourth form of transformer.

The transformer shown in Figures 1 to 3 comprises a tank 10 within which the transformer core and winding structure is housed. This structure is shown diagrammatically and is referenced 12.

The oil cooling system of the transformer is located externally of the tank 10 and is generally referenced 14. A tank outlet pipe 16 leads from an outlet at the upper portion of the tank 10 to the system 14 and a tank inlet 18 leads to the lower portion of the tank 10 from the system 14. The outlet pipe 16 communicates with a horizontal header 20 and a bank of parallel radiator tubes 22 project horizontally from the header 20 and at right angles thereto.

A second header is shown at 24 and an inclined pipe 26 leads downwardly from the header 24 to the inlet 18. The pipe 26 has the dual function of supporting the header 24, and hence the outer ends of the tubes 22, and of feeding cooled oil back to the inlet 18.

If reference is made to Figure 2, it will be seen that the tubes 22 are of flattened elliptical shape.

While the transformer is running, heat is generated and, entirely by thermo-syphonic action, the oil flows along the path indicated by the arrows A. Specifically, hot oil rises in the tank 10 and exits via the outlet into the pipe 16 and cold oil is drawn into the tank through the inlet 18. It will be understood that the terms 'hot' and 'cold' are used relatively to one another in this context and not with respect to ambient temperatures. In practice, the oil re-entering the tank 10 is at a temperature considerably above ambient. Cooling of the hot oil occurs as it flows through the tubes 22. Dissipation of heat from the tubes 22 results in a natural cooling draught being created, as indicated by the arrows B, which draught flows upwardly through the inter-tube spaces. It will be noted that the oil cooling circuit does not include a pump or any other means for forcing the oil through the cooling system, and furthermore no fan or other arrangement is provided for creating a forced draught of air through the inter-tube spaces.

Turning now to Figures 4 to 6, the transformer illustrated in these Figures also has a tank 10, a core and winding structure 12, and an external cooling system 14. The hot oil outlet pipe from the tank 10 to the cooling ssytem 14. The hot oil outlet pipe from the tank 10 to the cooling system 14 is shown at 16^{11} and the inlet from the cooling system to the lower end of the tank is shown at 18.

A pipe 26^{1} leads down to the inlet 18. In this form of transformer, the outlet 16^{11} opens into the upper part of a vertical header 28 (see particularly Figure 5). The reference numeral 30 designates a further vertical header which is spaced laterally from the header 28, the headers being connected by tubes 22^{1}. Within the header 28 there is a baffle 32 which prevents flow of oil from the outlet pipe 16^{11} to the lower end of the header 28. Similarly, there is a baffle 34 in the header 30, this baffle preventing flow of oil directly from top to bottom of the header 30.

The tubes 22^{1} are arranged in three banks referenced 36, 38 and 40. Within the header 28, the baffle 32 prevents direct oil flow to the bank 38. As a consequence, flow is through the bank 36 to the header 30 and thence, because vertical flow to the pipe 26^{1} is prevented by the baffle 34, through the bank 38 and back to the header 28. A third pass occurs through the bank 40 to the header 30 and thence to the pipe 26^{1}, which leads to the inlet 18.

Once again, flow through the cooling system is designated by the arrows A and natural air flow is designated by the arrows B in Figure 4. Oil flow is dependent entirely on thermo-syphonic action (the cooling circuit not including a pump) and air flow through the inter-tube spaces is again dependent entirely on natural convection.

In Figures 7 to 9, the references employed correspond, so far as possible, to the references used in the earlier Figures. The tank is referenced 10^{1}, the core 12^{1} and the cooling system 14^{1}.

An outlet pipe 16 leads upwardly through an upper cover 42 of the tank 10 and enters a header 44 from below. A single bank of tubes 22^{11} extends parallel to, and above, the upper cover 42 to a header 46. A pipe 48 extends downwardly from the header 46 to the inlet 18.

A consevator vessel 50 is mounted on the cover 42 by means of one or more hollow supports 52. The support or supports 52 serve additionally to connect the interior of the tank 10^{1} to the interior of the conservator vessel. It will be understood that the outlet pipe 16^{1} and the support or supports 52 can lead throuhg the upper part of one of the side walls of the tank 10^{1}.

Oil flow throuhg the transformer tank 10^{1} and its cooling system 14^{1} is shown by the arrows A in Figure 8 and air flow is shown by the arrows B in Figure 7. It will be understood that the spacing between the bank of tubes 22^{11} and the cover 42 must be sufficient to allow a free flow of cooling air to enter as shown by arrows B. It will further be understood that the transformer tank 10^{1} itself radiates a certain quantity of heat and that if there is insufficient spacing between the tubes 22^{11} and the cover 42, then not only will flow of cool air be restricted but heat radiated from the cover 42 will affect the tubes 22^{11}.

In a further constructional form, which has not been illustrated, the conservator vessel 50 is divided into two parts by a vertical or inclined baffle. The hollow support or supports 52 open into the vessel on one side of the baffle and the inlet 16^{1} opens into the vessel on the other side of the baffle. The header 44 is omitted and the tubes 22^{11} extend directly from the conservator to the header 46. Thus, in this form, that part of the conservator vessel into which the outlet pipe 16^{1} opens acts as the header. Economies in material and labour costs result from the use of the conservator vessel for this two-fold purpose.

In the drawings, the tubes 22, 22^{1} and 22^{11} are shown as being exactly horizontal. This is the preferred orientation of these tubes although it is possible, instead of arranging them horizontally, to arrange them at angles of up to 40 degrees with respect to horizontal. Applicants have found in experimental work that the more the tubes are inclined, the more the cooling efficiency falls off. In their opinion inclining the tubes does not give rise to any advantages over horizontal tubes which are particularly worthwhile. However, it will be understood that, if the transformer has banks of tubes as shown in Figure 5 and these tubes are inclined, one relatively small advantage is that it is possible to place the headers 28 and 30 closer to one another without reducing the lengths of the tubes.

If desired, the single bank of tubes shown in Figures 7 to 9 can be replaced by two or more vertically spaced banks of tubes.

While a single outlet pipe 16, 16 and 16^{11} has been illustrated in each of these embodiments, it will be understood that there can be a series of such outlet pipes along the length of the tank 10, each outlet pipe communicating with the header 20 (Figures 1 to 3) or 44 (Figures 7 to 9). Similarly, there can be a plurality of inlets 18 and pipes 26, 26^{1} or 48. Alternatively, one or more pipes 26, 26^{1} or 48 can lead to a header extending longitudinally near the base of the tank, and a plurality of inlets can lead from this header into the tank. Such arrangements may be desirable where the tank 10 is relatively long and it desired to create flow throughout a substantial part of the length thereof.

If desired, the tubes 22, 22^{1} and 22^{11} may be finned so as to increase the area from which heat is radiated. However, care must be taken to ensure that the fins do not so constrict the passageways between the tubes as to inhibit the creation of the necessary natural cooling flow.

Turning now to Figures 10 and 11, the transformer shown in these Figures comprises a tank 54 within which the transformer core and winding structure (not shown) is housed. The tank 54 is strengthened by horizontal stiffeners 56 and includes side plates 58, a bottom plate 60 and a top cover 62. Two sets of wheels or rollers 64 support the transformer. Axles 66 for the wheels 64 pass through parts of the side plates 52 which project downwardly beyond the plate 60. Jacking lugs are shown at 68.

The high voltage terminal structure of the transformer is illustrated at 70, the main low voltage terminal structure at 72 and an auxiliary low voltage terminal structure at 74. A drain valve for the transformer oil is shown at 76.

An oil cooling system 78 of the transformer is located externally of the tank 54 and above the top cover 62. The system 78 comprises a tank outlet pipe 80 which leads from the upper portion of the tank 54 to the central part of an upper header 82, and a tank inlet pipe 84 which leads from the central part of a lower header 86 to the lower portion of the tank 54. Two further headers 88 and 90 extend parallel to and below the header 82, and two more headers 92 and 94 extend parallel to and above the header 86. Two banks of five tubes 96 interconnect the headers 82 and 94, a further ten tubes interconnect the heads 88 and 92, and two further banks of five tubes interconnect the headers 86 and 90. As can best be seen from Figure 11, the banks of the tubes are close to the ends of the various headers so that, at each of the three horizontal levels, the two banks of tubes are spaced apart horizontally. It will also be seen that the tubes 96 are similar in cross sectional shape to the tubes 22, 22^{1} and 22^{11}.

The header 94 is connected to the header 92 immediately below it by short vertical pipes 98 and similarly the header 88 is connected to the header 90 immediately below it by short vertical pipes 100. Between the headers 82 and 88, and 92 and 86 there are supports 102 which can, if desired, be blanked-off pipes. Form the above it will readily be understood that oil flows along the pipe 80 to the header 82, along the tubes 96 of the two upper banks to the header 94, down the vertical pipes 98 to the header 92, along the tubes 96 of the two intermediate banks to the header 88, then down the pipes 100 to the header 90, along the two lower banks of tubes 96 to the header 86, and then back to the tank 54 via the pipe 84. Direct flow between the headers 82 and 88, and 92 and 86 is prevented so that all the flowing oil must make three passes through the tubes 96.

An oil conservator tank 104 is connected by pipe 106 to the tank 54, there being an oil and gas relay 108 in the pipe 106. A gauge 110 is provided for indicating the oil level in the conservator tank 104 and a thermometer 112 indicates the temperature of

the oil emerging from the tank 54. A dehydrating breather for permitting water vapour to escape from the conservator vessel 104 is shown at 114, and the conservator drain valve at 116.

The banks of tubes 96 lie laterally of the tank 54 as can be seen in Figure 11. Furthermore, the headers 82 and 86 to 94 are located beyond the ends of the tank 54. This is best illustrated in Figure 10. Thus, in plan, the tubes 96 and the headers define a rectangle the inner dimensions of which are larger than the dimensions of the top cover 6. Consequently, after removal of the pipes leading to the conservator tank 104, the top cover 62 can be removed followed by the transformer core and winding structure without the necessity of disturbing the radiator tubes and the headers.

WHAT WE CLAIM IS:—

1. An electrical transformer comprising a transformer tank which houses the transformer core and winding structure, and an oil cooling system the flow of oil through which results entirely from thermo-syphonic action, said cooling system being connected to an upper portion of said tank so that heated oil can flow from the tank to the cooling system and being further connected to a lower portion of said tank so that cooled oil can flow from the cooling system to the tank, and said cooling system comprising a first header, a second header spaced from the first header, and a bank of side-by-side radiator tubes connecting said first and second headers, the longitudinal axes of the tubes being arranged at an angle not exceeding 40° with respect to the horizontal, and a plane containing the longitudinal axes of the tubes having a longitudinal axis which is parallel to the axes of the tubes and a transverse axis which is substantially horizontal.

2. A transformer as claimed in Claim 1, wherein said tubes are inclined at an angle of not more than 20 degrees with respect to the horizontal.

3. A transformer as claimed in Claim 1, wherein said tubes are horizontal.

4. A transformer as claimed in Claim 1, 2 or 3 wherein said tubes are elliptical in cross-section with their maximum dimension vertical.

5. A transformer as claimed in any preceding claim, and comprising more than one bank of tubes, the tubes in each bank being side-by-side, and the banks being connected in series with one another and arranged one above the other.

6. A transformer as claimed in any preceding claim, wherein said tubes lie alongside a side wall of the tank and extend parallel thereto.

7. A transformer as claimed in any one of Claims 1 to 4, wherein said bank of tubes and said headers are above the level of the top of said tank.

8. A transformer as claimed in Claim 5, wherein said banks of tubes and said headers are above the level of the top of said tank.

9. A transformer as claimed in any one of Claims 1 to 4, in which said first header is connected by a tank outlet pipe to said upper portion of the tank, and said second header is connected by a tank inlet pipe to said lower portion of the tank.

10. A transformer as claimed in Claim 9, wherein one of the headers lies alongside a side wall of the tank, and said radiator tubes extend from said one header in the direction away from said side wall.

11. A transformer as claimed in claim 10, wherein said first header lies alongside said side wall, and wherein said tank inlet pipe extends downwardly from said second header to said lower portion of the tank and serves as a support for the second header.

12. A transformer as claimed in any one of claims 1 to 4, wherein said tank has a cover and said radiator tubes are in two groups, the two groups of tubes and the headers together, in plan, defining a structure the internal dimensions of which are greater than the dimensions of said cover, said structure lying above the level of the top of the tank and the arrangement being such that said cover can be lifted and lowered through said rectangular structure.

13. An electrical transformer substantially as hereinbefore described and as illustrated in the accompanying drawings.

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1548633 COMPLETE SPECIFICATION

4 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

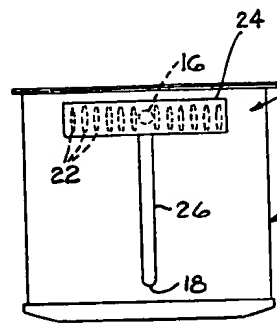

FIG. 2

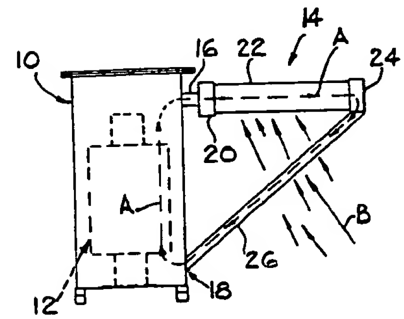

FIG. 1

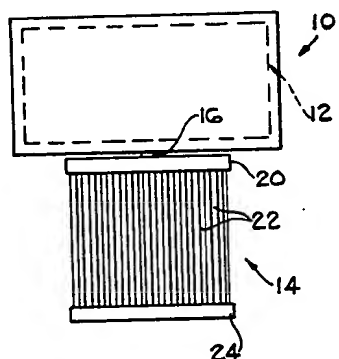

FIG. 3

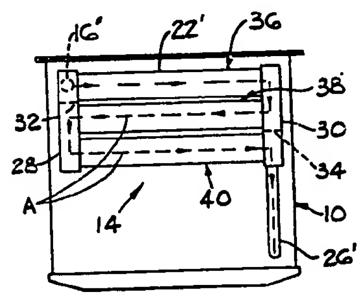

FIG. 5

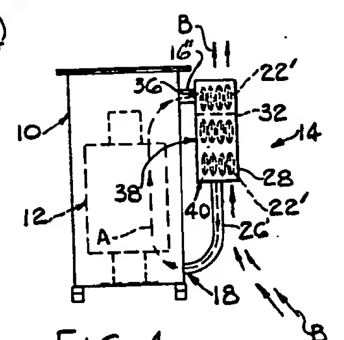

FIG. 4

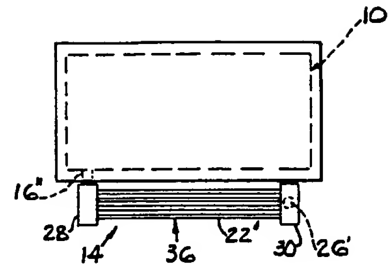

FIG. 6

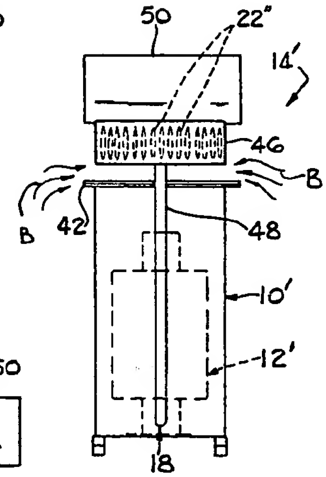

FIG. 7

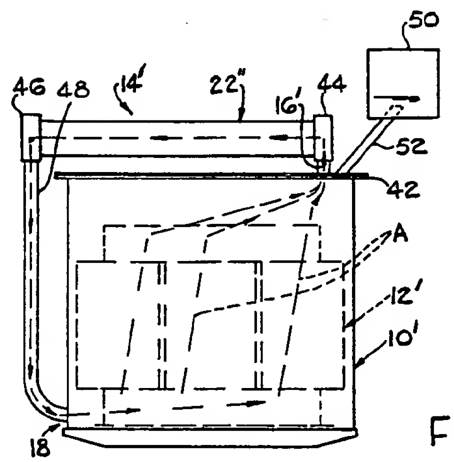

FIG. 8

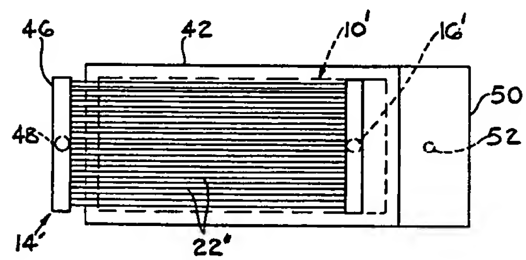

FIG. 9

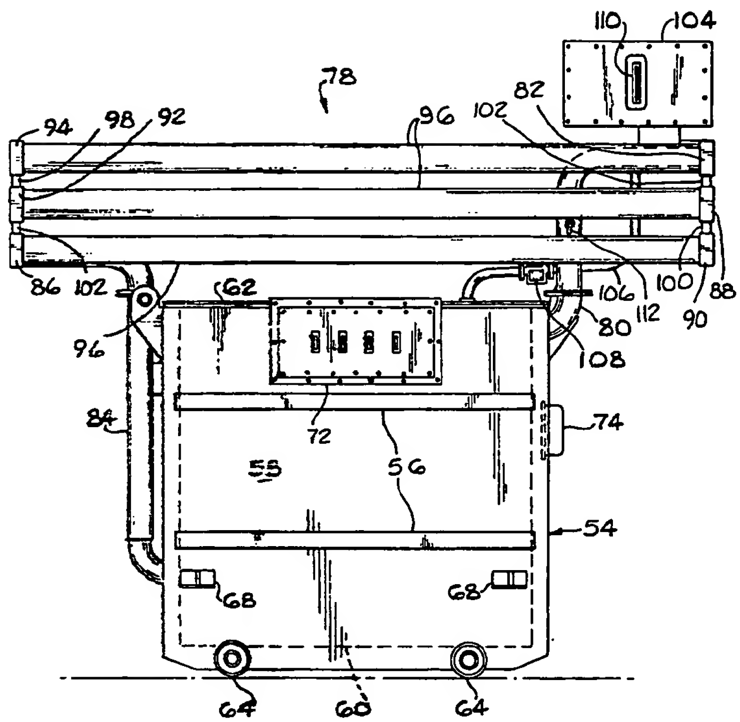
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FIG. 10

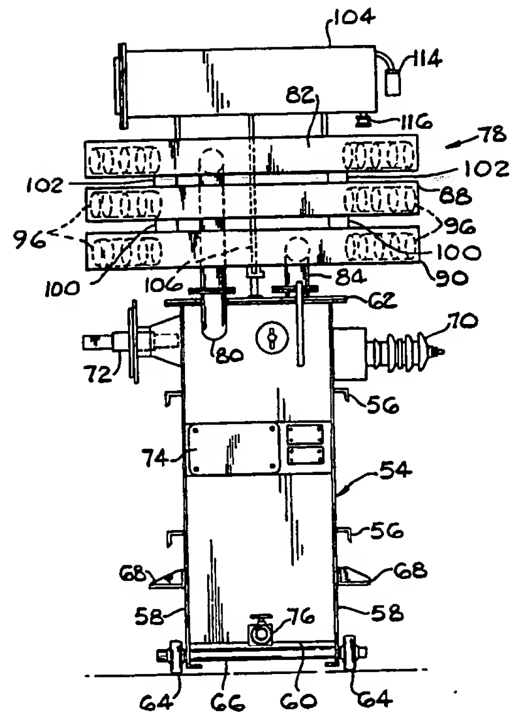
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FIG. 11